A Study of the Undercooling Behavior of Immiscible Metal Alloys: The Absence of Crucible-Induced Wetting and Nucleation

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In many metal binary systems, there exists a region where the two phases in the liquid state will not mix; i.e., they are immiscible. In processing these binary systems for commercial or scientific applications, decomposition of the homogenized liquid into two separate liquid phases will occur during cooling. Because of density differences between the two liquid phases, processing of these systems in a gravitational field will result in a layered structure with the lighter phase at the top, the heavier phase on the bottom. Such difficulties have plagued the pursuit of commercially important materials such as Ag-Ni and Al-Pb for electrical contact and self-lubricating bearing uses, respectively.

Attempts have been made to process composite, immiscible systems having uniform metallurgical structures of either aligned rod-like structures, or uniform, finely dispersed second phase within the majority phase matrix. Because of the larger particle interface-to-volume ratio in a finely dispersed alloy, the latter structure would potentially be more viable for commercial application.

Microgravity materials processing has the possibility of producing fine, homogeneously dispersed immiscible alloys. The low-gravity environment of a drop tube or space experiment could greatly reduce sedimentation and convection and thus reduce or eliminate separation during cooling through the two-liquid portion of the phase diagram. However, space flight experiments to date have produced disappointing results in that massive segregation still occurs during solidification in crucible contained experiments. It appears that separation of the liquid phases is due to mechanisms other than sedimentation alone. Research activities have since focused on the evaluation of these different mechanisms which would cause separation in either an Earth or a low-gravity environment.

To achieve the above studies, the environment provided by the MSFC 105-Meter Drop Tube Facility has been utilized. These conditions are ideally suited to prevent the sedimentation effects and the crucible-induced wetting and nucleation phenomena. Research in a truly containerless, low-gravity environment should provide much information to the question of whether preferential wetting of the free surface occurs and more importantly whether it can be controlled. Over the past year effort has been centered on initial studies of a number of immiscible systems. From these initial studies, three representative systems, those of Ni-Cr, Ga-V, and Ti-Ce have been selected for more in-depth study. Initial processing and analysis of samples from these three systems indicate a wide range in the separation behavior after processing. In addition there is a range in undercooling behavior depending on sample composition, environment pressure, and amount of overheat. The next year studies will continue with the intent of concentrating on the selected representative systems.

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Biographical Sketch: Dr. Michael B. Robinson came to Marshall Space Flight Center in September 1976, and currently is a member of the Crystal Growth and Solidification Physics Branch in the Space Sciences Laboratory. He currently serves as project scientist for the MSFC 105-Meter Drop Tube, for the modular electromagnetic levitator, and the German TEMPUS space flight electromagnetic levitator, scheduled to fly aboard the Space Shuttle on the International Microgravity Laboratory–2 mission. In addition, Robinson is currently co-investigator on two flight programs, one involving the study of the effect of microgravity on the nucleation distribution of pure metals, and the other involving directional solidification under microgravity conditions and influences of magnetic fields. He also serves as co-investigator on a ground-based research program involving undercooling, nucleation, and solidification studies. Robinson received his M.S. in physics from the University of Alabama in Huntsville and his Ph.D. in materials science from Vanderbilt University in May 1988.